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THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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THE FOUNDER OF ENGLISH ASTRONOMY

Horrox observing the Transit of Venus, December 4, 1639.

From a painting by Eyre Crowe, A.R.A. Reproduced by permission from the original (in the Walker Art Gallery) in the possession of the Corporation of Liverpool.

From a painting by [illegible] in the possession of the Corporation of Liverpool.

TRANSIT OF VENUS

William Crabtree observing the Transit of Venus, December 4, 1639.
From a mural painting by Ford Madox Brown in the Manchester Town Hall.
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HORROX

BY ALBERT D. WATSON

"The pride and boast of British Astronomy."
—SIR JOHN HERSCHEL.

It takes a long time to discover anything. After a lapse of nearly three hundred years, the world can hardly yet be said to have discovered Horrox. By a vast majority of the people of his own country, his name, which should be a household word, has not even been heard. Nevertheless, he is one of the most remarkable scientific geniuses of the ages. His early death, which cut short his labors, leaving them to be completed by others to whom he pointed the way, gave to *them* all the glory of the achievements in which his pioneer work was a chief factor. The greatest name in the scientific world for two hundred years after Horrox is that of him who took up the golden thread of truth which this young man laid down.

Many years ago, at the suggestion of the late Mr. G. E. Lumsden, F.R.A.S., at that time the President of our Society, my attention was first directed to the life and work of Horrox. I have since learned to love the man and to admire his genius, and from this fact arises the impulse to lay this tribute to his

worth upon the altar of his memory. I would that the task were in the hands of some one whose authority in the scientific world might have established forever in the minds of all the right to a place in the first rank of one who, had he lived out half his days, would have been recognized as a genuis equal to Copernicus, Kepler, Newton or Galileo.

Amateurs have risen to merited eminence in many fields. Nowhere is this fact better illustrated than in the science of Astronomy. Men of various vocations have devoted their talents to the study of the stars, and made effective contributions to the sum of human knowledge. Indeed most of those whose names are eminent in astro-physics were at the first engaged in other vocations. It is well known that Copernicus was a priest in the Frauenburg, and it was in moments spared from his sacred duties in this capacity that he made those unwearying observations of the motions of the planets which, in their analysis, led to the discovery of the true system of solar relations and revolutionized the whole science of astronomy. Sir William Herschel, the virtual founder of sidereal science, was a musician. Olbers, of comet fame, was a doctor of medicine. Helmholtz, whose labors will always be so intimately associated with the law of the Conservation of Energy and other important astro-physical investigations, was also a doctor of medicine. Huggins, who showed that "the chemistry of the solar system prevails, essentially at least, wherever a star twinkles," was a private gentleman. Huygens, who cleared up many of the mysteries of Saturn's rings was a lawyer. The list might be enlarged indefinitely.

Of the learned professions, the church especially has devoted its best genius to the furtherance of this science. The lofty fields of celestial motion are fittingly symbolic of those sacred contemplations and emotions to which the preacher of righteousness and truth consecrates his powers. Many instances might be adduced showing the contributions of the church to astronomical science. Kepler, as is well known was preparing for a clerical life when his genius for mathematics brought him an

offer which threw him into the company of Tycho Brahe and made him an astronomer. We have already instanced Copernicus. Innumerable clerics have since his time devoted their powers to celestial investigations. Among these, who does not owe much to Dr. Thomas Dick? Who in these days has failed to reap much star-lore from the fields sown by Prebendary Webb?

Horrox, like Copernicus, was a churchman, having been curate of Hoole in 1639-1640. His untimely death serves to accentuate his remarkable genius. Many instances of early achievement have been known. In some cases the work of later years has been ascribed erroneously to early life. In the case of Horrox, his contributions to science are, unfortunately, too clearly defined by death to admit of such an error. It may be added that probably no greater astronomical claim was ever established in so brief a lifetime.

The chronological relation of our subject to the history of science may be stated in a few dates and facts. Seventy-five years before Horrox's birth, Copernicus died. His published work, *De Revolutionibus Orbium Cœlestium*, was brought to him only when he lay on his death-bed. Nevertheless, we know that the modern theory of solar and planetary relations was pretty well established before Horrox's time. Kepler died when the English boy was only eleven years of age. He had published his now famous Laws of celestial motion in 1619, the year of Horrox's birth. Passing from Germany to Italy, we find that Galileo had observed the moon through the telescope in 1610, nine years before the publication of Kepler's Laws. The Italian outlived the English youth by only one year. Milton, then thirty years of age, had looked through Galileo's "optick glass" in 1639, the same year in which Horrox, for the first time in the history of the race observed a transit of Venus before the sun. The fame of these men greatly overshadowed that of the English boy, yet Horrox made many corrections of Kepler's calculations, detecting a serious omission in his predictions and verifying the correction. Whatton, speaks of Horrox thus: "He estimated

the sun's horizontal parallax more accurately than any one who came before him: it had previously been supposed to be at least two minutes, and even Kepler had stated it at 57″; but Horrox proved that it could not exceed 14″, which was within one and a half seconds of the value assigned to it by Halley sixty years afterwards. Horrox's reduction of the sun's parallax is very remarkable; for though he had not diminished it enough, Newton in the first edition of the *Principia* (1687) hesitated in following him so far. 'I am not quite certain,' says Newton, 'about the diameter of the earth as seen from the sun. I have assumed it to be 40″, because the observations of Kepler, Riccioli, and Vandelini do not allow of its being much greater. The observations of Horrox and Flamstead make it somewhat less.'"

Newton acknowledged that Horrox was the first to discover the motion of the moon to be an ellipse about the earth, with the centre in the lower focus. In *De Mundi Systemate*, Newton says: "There are many inequalities in the moon's motion not yet noticed by astronomers. They are all deducible from our principles, and are known to have a real existence in the heavens. This may be seen in the hypothesis of Horrox which is the most ingenious, and if I do not deceive myself, the most accurate of all." Flamstead declared the hypothesis of Horrox for settling the movements of the moon to be "the most exact that had ever been originated."

Halley, after speaking of the lunar theories of various men, proceeds as follows: "but that one alone of our Horrox which attributes to the moon's orbit a libratory motion of the apsides, and a variable eccentricity, seems to approach the truth of nature; for it represents the diameters more agreeably to observation, and shows her motion more accurately than any hypothesis which I have hitherto seen." Whatton says, "Sir Isaac Newton largely availed himself of Horrox's suggestions to explain the general principles of perturbation, as laid down in the 66th proposition of the first book of the *Principia*. These improvements are so substantial that there is no difficulty in ascertaining the author to whom they are to be assigned."

One of the best articles on Horrox is that of the late Agnes M. Clerke in the *Dictionary of National Biography*. The same article is to be found in *Nature*, of July 19, 1873. This writer quotes as follows: Professor Grant in *History of Physical Astronomy*, "His name would assuredly have been a household word to future generations if his career had not so soon been brought to a close." Hearn, writing in 1723, speaks of this "very strange unaccountable genius . . . . . a prodigy for his skill in Astronomy, who, had he lived, in all probability, would have proved the greatest man in the whole world in his profession." (Mss. Diary, in the Bodleian Library, No. 102, Page 62).

Horrox at an early age arrived at a profound conviction concerning the harmonies of nature. He expresses that conviction in these words: "Astronomy is natural and true. The sea is agitated with the winds; but the ether is clear and open, without wind or any other resistance. The bodies of the planets are solid and firm. Now as a slinger aims accurately, and projects his weapon with certainty, notwithstanding the resistance of the air, why may not the heavenly bodies, in like manner, rotate by an eternal law?" This, mark you, was forty-five years before the publication of the *Principia*.

Sir Isaac Newton, upon publication of his own work, expresses himself as being "glad that the world will enjoy the writings of that excellent astronomer, Horrox." Many other scientists of the first rank have spoken of Horrox in the highest terms. Among these are Foster of Gresham College, Ferguson, Brinkley, Sir John Herschel, Dr. Whewell, Lord Brougham, Professor De Morgan and Airy.

Horrox corrected the solar diameter to 31′ 30″. From the instantaneous disappearance of the stars during an occultation of the Pleiades on March 19, 1637, he inferred the extreme minuteness of the stellar apparent diameters, correcting Galileo's estimate and showing that as the moon moves half a second of arc in a second of time, the apparent diameter of the stars must be a very minute fraction of a second. He strongly recommended the decimal system nearly 300 years ago, that is within

thirty years of the date when it was first suggested by Simon in 1602.

The writings of Horrox seem to have been ill-fated. Some of them were taken to Ireland by his brother Jonas and lost. Some were destroyed during the civil war of the period. Others were burned in the great fire of London of 1666. The name of Horrox narrowly escaped oblivion. The *Venus in Sole Visa*, however, was published, though in a foreign tongue, in 1662, and other papers followed shortly after.

It was about this time that Newton began to investigate the subject of Gravitation. We know that he read the writings of Horrox bearing on the question. He merely took up the study where Horrox laid it down. Newton, in the first book of the *Principia*, published in 1687, acknowledged his indebtedness to Horrox and expressed his admiration for the youth whose generalization had identified the sun's pull upon the moon with terrestrial gravity. Surely we may go as far in this matter as Newton gives us warrant for. (See Horrox's *Opera Posthuma*, page 295.)

Jeremiah Horrox, (or "Horrocks" as it is sometimes written) was born at Toxteth, Lancashire, within three miles from Liverpool. The astonishing range of astronomical lore shown in his letter to Crabtree, dated June 21, 1636, and the fact that he was a curate when twenty years of age, have led to doubt as to the accuracy of his birth-date as usually accepted, (1619), but there is no sufficient ground for doubt on this question. We know that he died on January 3rd, 1641, so that we may reasonably presume that his demise took place while he was still in the first year of his majority.

Horrox was entered at Cambridge May 18, 1632, but left the college early in 1635 without having obtained a degree, and having learned but little mathematics and no science. His parents seem to have been poor. This fact may afford explanation of his leaving Cambridge so early. He returned to Toxteth and earned a pittance as a tutor in his native village.

In 1636 he met with Wm. Crabtree, a clothier and amateur

astronomer of Broughton, near Manchester. He was a friend also of Gascoigne, the inventor of the micrometer. The latter survived Horrox only three years for he was killed in the battle of Marston Moor in 1644.

In 1638, Horrox obtained a small telescope for which he paid half-a-crown. This is the only instrument he ever owned.

Early in 1639, he was curate in Hoole, a small village in Lancashire, about eight miles from Preston, and not far from his earlier home. He retained this position for about a year, resigning in May, 1640. His annual stipend was only 41 pounds. He was able slightly to increase this income by acting as tutor in the village. Thus he eked out a living, and he never complained of poverty.

Horrox recorded an astronomical observation in Toxteth on June 7, 1635, but at this time was hampered by a lack of mathematical training, the absence of books, and the fact that he was not as yet the possessor of a telescope. He procured Lansberg's Tables, but found them very inaccurate and spent much time in correcting them. When he met Crabtree he was advised to read Kepler's works. This he did, but finding some errors even in these, he set to work to revise them. Desiring further to extend his knowledge, he made a list of twenty-two books that he wished to acquire. In this list, not one was written by an Englishman.

Horrox was of that peculiar type of genius who sees the whole in its part, who estimates the circumference of a circle from its minutest segment. Thus he divined laws and relations hitherto unsuspected. It was he who first showed the moon's motion to be harmonious with Kepler's first law by establishing the ellipticity of the lunar orbit. While studying the moon's librations, he found that Ptolemy's theory of their causation was untenable, as it was incompatible with modern estimates of the moon's diameter. The causes of evection were stated by him, and the annual equation was shown to depend upon the combined control of the earth and the sun. He used the experiment of the circular pendulum for illustrating the action of a central force.

In revising the work of Kepler, Horrox found a slight error by which the great German astronomer had been led to predict that the next two transits of Venus would occur in 1631 and 1761 respectively. The transit of 1631 was not observed, cloudy skies prevailing at the time of its occurrence. Astronomers, relying on Kepler's authority, appear to have dropped the subject from their thought and left the observation of these transits to future generations.

Not so Horrox. While revising Kepler's Tables, he found enough inaccuracies to warrant a closer scrutiny and this revealed a slight error, which had thrown the German off the track, so that the transit of 1639 had escaped him. After the most careful confirmation of his estimates, Horrox concluded that on the afternoon of Sunday, November 24, 1639, at about three o'clock or a little after, a transit would take place.

No effort was omitted in order to make his observation effective. He wrote to his friend Crabtree and to his brother Jonas asking them to observe carefully, each in his own locality, on the day in question. He told them precisely what to expect, and asked them to report accurately, so that notes might be compared. He specially desired of them a precise estimate of the diameter of Venus as it appeared on the face of the sun, and expressed the conviction that it would be found to be only slightly in excess of one minute or arc.

He now prepared his own telescope in the house of Mr. Carr, with whom he was lodging, so that the sun's image would fall on a piece of white paper placed at right angles to the axis of the telescope; in this way the image of the sun could be seen much larger than by looking directly through the instrument. He drew a circle six inches in diameter on the paper, and on its circumference marked off 360 degrees so that he might more readily determine the position of the planet.

The difficulties of this observation can better be understood when we remember the fact already stated that the telescope he used cost him only a half-crown.

Horrox was almost certain that the transit would take place after three o'clock on Sunday, but in order to be sure, no chances were taken ; he observed from time to time on Saturday afternoon, rose at sunrise the next morning, and kept watch till nine o'clock. Back again at ten, he pursued his observation till the hour for divine service in the afternoon. He says, referring to this, that more important duties called him away. Here, the devout churchman speaks. Whatever our opinion may be as to his estimate of the comparative importance of these duties, we must all commend his simple fidelity to what he conceived as his duty to his people. The modern astronomer is in danger of estimating too highly the self-sacrifice with which Horrox appears to have obeyed a law for which obedience he was so ill-repaid in the coin of this world, but so well rewarded in self-approval and the consciousness of faithfulness to a real duty. Crabtree also was interested in the transit and would see it if it was to be seen at all. Horrox was so sure that the transit would occur between three and four o'clock, that he felt little difficulty in leaving before that time ; however, he hurried back after the service to resume his observation. Arriving at Carr's house at 3.15, he found a round black disc just within the limb of the sun at the internal contact. The transit was under way. (Plate XX). Jeremiah Horrox, aged 20 years, had predicted it to the hour, almost, indeed, to the minute, being the first in all time to see such a phenomenon.

He continued his observations till 3.50, when the sun was too low to follow it further down the west. His brother Jonas, who was observing in Liverpool, had not been able to see the transit on account of the cloudy weather which prevailed there. Crabtree saw the planet very well at his home in Broughton, but during a brief portion of its transit over the face of the sun. (Plate XXI). He reports himself so overcome with joy that he failed to make the mathematical calculations required. The sun was clouded again in a few moments.

Horrox wrote an account of the phenomenon, and made several Latin copies of his recital. Only two of these survived.

One was obtained by Crabtree after the death of his friend, and the other fell into the hands of Hevelius, who had it published in 1662. Horrox was not in Hoole much more than a year, but went back to Toxteth for a time. His occupation there is not known. He wrote to Crabtree saying that he was unable to make observations at night. Some remarks about his study of the tides suggest that possibly his delicate health prevented his being out in the night air, but not in the day time when he could study the tides. No one seems to have regarded this theory seriously, as no discussion of it is to be found in any of the memoirs.

We know that in December, 1640, he wrote to Crabtree arranging a meeting on January 4, 1641, but at the hour appointed the body of Horrox was lying dead in the home of his childhood. We do not know the cause of his death. A careful study of the five years of his life which were scientifically productive, shows how various and how remarkable were his achievements during this period. We cannot but feel that England has never realized what she lost in the untimely passing of this remarkable youth.

The present century will be past before another transit of Venus occurs to waken an interest always too languid in this wonderful youth. The members of the Royal Society rightly estimated Horrox's writings upon other themes more highly than those upon the transit. It is not right that this hero of the world of science should wait so long for a recognition which if based upon his observation of that one phenomenon must ever be inadequate. Horrox's name has a right to a higher place and to a more universal fame. The discoverers of Gravitation and its Law are Horrox and Newton. This is the proper order of the names. This is the order which Newton himself would probably have set had a question of credit ever arisen in the mind of so great a man in relation to his own interest. Horrox discovered Universal Gravitation, Newton stated its Law.

A monumental tablet in the church at Hoole, another in Carr's home, and another in the church at Toxteth Park, were

supplemented by a marble slab in Westminster Abbey to immortalize the name of Britain's first great astronomer. It is not enough. People may be forgotten in Westminster as effectually as anywhere else. It is not for the sake of Horrox that his name should be remembered. On a memorial of Lord Nelson in the city of Edinburgh, is an inscription somewhat as follows: "The people of Edinburgh erected this monument to Horatio Lord Viscount Nelson, not to express their unavailing sorrow for his death, nor to celebrate the matchless glories of his life, but by his example to teach their sons, when occasion calls, like him to die for their country." It is in the spirit of this inscription that appeal is made for the immortality of this wonderful youth, who while yet in his 'teens was able to correct the mathematics of Kepler and Galileo and make discoveries that must always take high rank in the scientific world. Not only did he exhibit scientific taste, but together with mathematical accuracy, were combined the amiable qualities of a friend, the profound devotion of a saint, the acumen and keen insight of a philosopher, and a love of nature and her sublime laws seldom surpassed. Such was the rare human harmony of this man that it requires no great credulity to believe that had he lived his name would have been universally honored, for he would then have received the credit for the discovery of that most profound of physical generalizations ever revealed to the mind of man, the Law of Gravitation, a discovery to which his finger was pointing when he fell.

Horrox was the first to show the courses of the comets to be curves and not straight lines, as they had hitherto been supposed to be. He wrote of the motions of Jupiter, Saturn, and of various comets, and showed that the tides gave probable support to the theory of the earth's rotation. But his interest in the astronomical observations of his friends was, if possible, even greater than that which he manifested in his own. In July, 1640, Crabtree had written him of some successful observations which he had been making in Broughton. Horrox, writing from Toxteth, replied: "Your letter alone has enough and more than enough to transport beyond all bounds a soul more master of

itself than mine. My emotion and gladness are such as you will more easily understand than I express."

Besides his philosophic faculty for generalization, Horrox possessed marvellous patience and persistence, wide-reaching activity, ambition, enthusiasm and self-confidence. His versatility is shown by his compositions in Latin and by his quotations in his letters, from Horace, Juvenal, and other Latin poets. He was a poet himself and wrote a good deal of verse, commending Kepler and Copernicus and the newer Astronomy of that age.

It is likely that the genius of this man was not inferior to that of Kepler or even to that of Newton. He is one of England's most wonderful products, the outstanding genius among his contemporaries. The German Kepler, and the Italian Galileo threw such a glare across the European lands that its brightness blinded even the scientists of England to the glorious achievements of their own son.

It is to be hoped that the name of Horrox will ere long be associated more intimately with those of his great contemporaries. The English boy was not unworthy of an equal place in that great astronomical trio.

The following is the inscription on the memorial tablet in Toxteth Park Church. (Plates XXII, XXIII).

. . . . . .

Venus in Sole Visa, November 24, 1639.

In memory of

JEREMIAH HORROX, one of the Greatest

Astronomers this Kingdom ever produced.

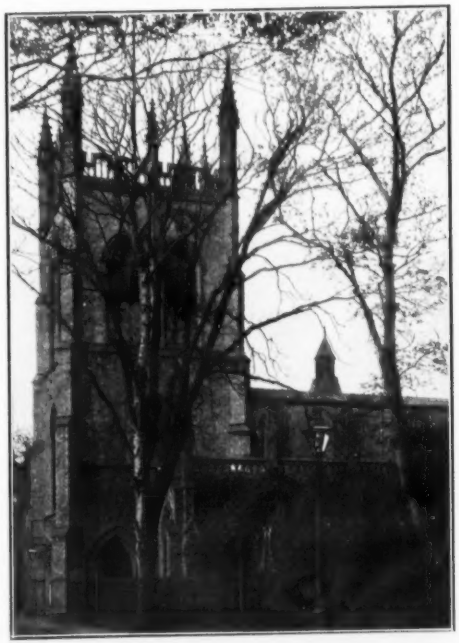
Born in Toxteth Park in 1619

Died in 1641, aged 22.

His observations were made at Hoole, eight miles from Preston,
where he predicted, and was the first person who saw
the transit of Venus over the sun.

This monument was erected by M. Holden, Astronomer, 1826.

. . . . . .



EXTERNAL VIEW OF ST. MICHAEL'S CHURCH, TOXTETH PARK, LIVERPOOL.

VENUS IN SOLE VISA NOV'24 1639
IN MEMORY OF
JEREMIAH HORROX ONE OF THE GREATEST
ASTRONOMERS THIS KINGDOM EVER PRODUCED
BORN IN TOXTETH PARK IN 1619
DIED 1641 AGED 22
HIS OBSERVATIONS WERE MADE AT HOOLE
8 MILES FROM PRESTON WHERE
HE PREDICTED AND WAS THE FIRST PERSON
WHO SAW THE TRANSIT OF VENUS OVER THE
SUN
THIS MEMORIAL WAS ERECTED BY
M HOLDEN ASTRONOMER
A D 1826

TABLET IN ST. MICHAEL'S CHURCH, TOXTETH PARK, LIVERPOOL.

From a photograph made with the permission of the Vicar, Rev. John Eyre

INTERIOR OF ST. MICHAEL'S CHURCH, TOXTETH PARK, LIVERPOOL,
IN WHICH IS THE TABLET TO HORROX

Recapitulating, we find the net results of Horrox's work as follows:

He was the earliest first-rate astronomer of Britain.

Corrected many of Lansberg's tables.

Corrected the estimated sun's horizontal parallax to 14″. Kepler had placed this at 57″. Newton places it at 40″ 45 years later. Horrox was within 1½″ of the value assigned to it by Halley sixty years afterwards.

Explained the irregularities of the moon's motions

Confuted the Ptolemaic theory of the moon.

Showed that "the heavenly bodies revolve in harmony with an eternal law."

Proclaimed Gravitation in this way 45 years before Newton, who admits this in his *Principia*.

Corrected the apparent Solar Diameter to 31′ 30″.

Inferred the extreme minuteness of the apparent stellar diameters.

Corrected Galileo's estimate of the same, and proved his conclusion.

Strongly recommended the decimal system in astronomical calculations 275 years ago.

Corrected many of Kepler's calculations.

Predicted accurately a transit of Venus which Kepler had overlooked, and which occurred November 24, 1639.

Was the first person to observe accurately a transit of Venus.

Showed the moon's orbit to be an ellipse, even Kepler not having known that the moon obeyed his first law.

Stated the causes of the lunar evection.

Showed the annual lunar equation to depend upon the combined action of the earth and the sun.

Thus he further established the idea of universal Gravitation.

Used the circular pendulum to illustrate the action of a central force.

Corrected the apparent diameter of Venus to a fraction over 1′ of arc, Kepler placed it at 7′.

Undertook a systematic study of the tides, of which the results were lost.

Supported the theory of the earth's rotation by reference to the behavior of the tides.

Showed the courses of the comets not to be straight lines as had been heretofore held.

Composed Latin verses in honor of Kepler and Copernicus and the newer Astronomy.

I confidently close this article with the statement already made, Horrox discovered Universal Gravitation; Newton stated its Law.

Toronto, Ontario.

THE ROTATION PERIODS OF THE PLANETS

By W. F. Denning

THE length of a day on the various planetary members of the solar system is a very interesting feature and one which is, in certain cases, very difficult to determine accurately. There is probably some unknown law, which, if discovered, would enable the various periods to be ascertained apart from the method of taking transits of markings on their surfaces. This law is probably one dependent upon the oblate forms of their globes, and upon their dimensions, distances from the sun and possibly other elements.

I have observed the following periods :—

	h	m	s	
Mercury	24	42		1882–1906
Venus	23	21		1881
Mars	24	37	22·7	1869–1904
Jupiter	9	55	36·57	Red spot Hollow 70 yrs. 1831-1900
"	9	50	15	Equatorial region mean 1880–1906
"	9	48 to 56	0 to 15	N. temperate region varies 8¼ minutes
"	9	55	19	S. temperate region
Saturn	10	37	56·4	N. temperate region 1903

The period for *Venus* is very uncertain. The markings are very faint and indefinite. The true period is probably $24^h\ 5^m$ or thereabout, estimating from analogies.

Mars — The correct period of rotation from recent observations and the most accurate measures by other observers directed to test the question is $24^h\ 37^m\ 22^s{\cdot}57$.

Jupiter's markings are very variable and their rates of motion

influenced by striking irregularities as well as by atmospheric currents in which they are carried along at different velocities.

Saturn displays very analogous phenomena to Jupiter. Sir W. Herschel obtained a value of $10^h\ 16^m\ 0^s{\cdot}44$ from certain inequalities in a quintuple belt visible in the planet's southern hemisphere in December 1793 and January 1794, and Professor A. Hall, derived $10^h\ 14^m\ 23^s{\cdot}8$ from a large white equatorial spot visible from December 7, 1876, to January 2, 1877. Herschel's probable error was 2 minutes, Hall's 2·3 seconds. In June, 1903, an extensive white spot was observed by Barnard in the planet's north temperate region. Many other observers saw this and a number of other markings in the same latitude. The rotation period as deduced by the writer from some hundreds of transits which he obtained by means of a 10-inch reflector, power 312, between July and December 1903, was $10^h\ 37^m\ 56^s{\cdot}4$.

The rotation has not been found of *Uranus* but several observers have given possible periods, from insufficient data, of about 10 and 12 hours. The true period probably lies intermediate between that of the small and large planets and is much greater than 12 hours. Lowell from spectroscopic measurements derived a period of 10¾ hours.

Belts have been distinctly seen on *Uranus* by means of some of the great telescopes, but it has not hitherto been possible to discern irregular markings affording a good clue to the rotation period.

Neptune probably rotates in a period slightly less than that of Uranus, but the exact time is quite an open question. Various guesses have been made. Maxwell Hall, of Jamaica, from certain variations in the planet's light inferred a period of 8 hours.

BRISTOL, ENGLAND,
May 2, 1915.

THE GREAT METEORIC STREAM OF FEBRUARY 9, 1913

By W. F. Denning

THIS remarkable phenomenon was fully discussed by Professor C. A. Chant and others in the Journal of The Royal Astronomical Society of Canada, for May-June, 1913, and subsequent numbers.

When last seen east of Bermuda by Col. W. R. Winter, it had been observed while passing over a lengthy track of about 2600 miles from north-west of Mortlach, Saskatchewan. In the Journal for November-December, 1913, I mentioned that, "judging from the aspect of the swarm as viewed from Bermuda it was not nearing exhaustion, but apparently quite capable of a further 1000 miles, or more, of flight across the North Atlantic Ocean."

In an endeavor to obtain the necessary evidence I wrote a letter to the *Nautical Magazine*, which was published in the number for April, 1914, and in which I enquired "whether any one on board ship between the Cape Verde Islands and Bermuda on the night of the 9th of February, 1913, after 10 p.m., saw anything of a brilliant meteoric phenomenon?" In the event of the spectacle having been witnessed I requested information as to the position of the objects and their direction of motion together with the time and the place of the vessel in latitude and longitude.

I have received a reply dated April 10, 1915, from Mr. A. V. Porter, of the S.S. *Bellusia*, and he writes as follows: — "I saw in the *Nautical Magazine*, for April, 1914, that you required more information about the great meteoric shower of 9th February, 1913. At noon of that date the S.S. *Bellusia* was in Lat. 17° 35′ N., Long. 51° 11′ W.; at 10.30 p.m. in Lat. 16° 39′ N.,

Long. 50° 15′ W. I was on the bridge from 8 to 12 p.m. At 10.30 p.m. I saw the sky lighted up with meteoric fire, starting at north and going by way of east to the south-east. Apparently the height was about 25° above the horizon, but not more than 10-12 miles east of the position of the steamer at that time, continuing until 11.05 p.m. It must have been travelling through the earth's atmosphere at the rate of more than 500 miles an hour and fragments were falling off as it passed along. It looked like red and white liquid fire. As soon as I noticed it I sent the apprentice, Wm. Black, to call Capt. J. Kiddie to witness the phenomenon. When we were in Norfolk, Va., in June, 1914, I wrote out a description of the event and Capt. Kiddie, myself, and the apprentice signed it, and it was mailed to the Hydrographic Office at New York, on June 13th, 1914."

I believe from all the facts of observation, and the circumstances that slow meteors are invariably rather low in the atmosphere, that the adopted position for the trace should come nearer Bermuda in the diagram, *Journal of the Royal Astronomical Society of Canada*, Vol. VII., p. 163. If we regard the distance of the meteors as 90 miles and the altitude as 30° the resulting height will be 54 miles. The objects had probably risen from about an average of 42 miles over the Ontario region, but there were obviously large differences in the individual fragments not only as to their vertical heights but also as to their transverse distribution.

The dimensions of the meteors were evidently very varied and this would bring about alterations in their relative heights while peculiarities of shape in the particles undergoing disintegration must have induced deviations from their original lines of flight as they encountered atmospheric resistance.

When seen from the S.S. *Bellusia* the height may have a little further increased. The fact that at Bermuda, Col. Winter estimated that the two leaders were equal in brilliancy to that of the moon affords additional proof that they were not very distant from the observer or from nearing final extinction.

The least distance of the *Bellusia* from the meteors was

probably 150 or 200 miles and if we deduct one third of Mr. Porter's altitude we get a real height of 57 miles which is not at all excessive and might be reduced were the actual facts known accurately.

Suffice it that Mr. Porter's testimony is in approximate agreement as to the time of appearance, position, height and direction of the meteoric phenomenon. We can hardly consider it as a mere coincidence. His observations were admittedly rough like the great majority of the other observations, but so far as they go must be regarded as significant.

I have written to Mr. Porter, also to the Captain of the *Bellusia*, and hope to ellicit further details which may more certainly prove that the meteors travelled half as far again (about 1300 miles) as that previously observed.

Mr. Porter states that the spectacle persisted until 11.05 p.m, extending altogether, therefore, over a period of 35 minutes. I do not understand this long duration, in view of the fact that the flight over Canada continued about 3 minutes only and that no lengthening out of the stream appeared to be in progress. Towards the end of its visible career it may, however, have altered its aspect considerably and further information must be awaited before the value of my correspondent's evidence can be fairly estimated. That the meteors did travel much further over the North Atlantic Ocean than the position afforded by Col. Winter's observation from Bermuda is certain, and people on board ships in that particular region must have viewed them and could supply us with just the information required were they cognisant of its value and knew where to send it.

BRISTOL, ENGLAND,
April 22, 1915.

CANADA-ALASKA BOUNDARY SURVEY

By Noel L. Ogilvie*

SINCE the famous London Tribunal of 1903, the work of delimiting the boundary between Alaska and British Columbia has been carried on by the governments of the two countries under the direction of the Commissioners, O. H. Tittman, Superintendent of the Coast and Geodetic Survey, for the United States, and Dr. W. F. King, Chief Astronomer, for Canada.

The initial point of the boundary at Cape Muzon is on the southern side of the southernmost of the small island, off the southern end of Dall Island, and where the curve of the low water mark is touched by a direct line drawn tangent from the boundary point "B" at the entrance to the Portland Canal. The line crosses Dixon Entrance and follows up the Portland Canal, thence following, more or less approximately, the many sinuosities of the very rugged coast of southeastern Alaska until it reaches Mt. St. Elias. The distance along the line from Cape Muzon to Mt. St. Elias in 887 miles, of which 180 miles is across water, leaving 707 miles of actual land boundary through the rugged coast country. The water part of the boundary is 80 miles from Cape Muzon to the mouth of the Portland Canal, leaving 100 miles of boundary along the Portland Canal.

Three classes of monuments were used in marking the boundary line. At the more important points or places where transportation was easy, an obelisk monument of aluminum bronze, about 5 ft. high and weighing about 300 lbs., is set, while at more inaccessible points a small conical monument, also of bronze, about 2½ ft. high and weighing about 55 lbs., is used. To govern the water boundary from Cape Muzon to the head

* In charge, for Canadian Commissioner, of field work on the Alaska-British Columbia Boundary.

of the Portland Canal, pyramidal reference monuments of concrete are placed at Cape Muzon and along each side of the Portland Canal at intervals to control the turning points of the boundary down the centre of this waterway. The boundary is shown on a map by dots and dashes connecting small circles down the centre of the Canal. The points of the Boundary indicated by these circles are referred to the monuments erected along each side of the Canal as mentioned above and these monuments are placed nearly opposite to the boundary point, so that the distances to it may be as small as practicable. The first two types of monuments are set in concrete, using about 200 lbs. of cement to the monument, with the proper proportion of sand and broken rock to make a good concrete. The only exceptions to this were where the small monuments could be set by grouting their fluted legs into holes drilled in the solid rock. The reference monuments along the Portland Canal are 14 inches square at the bottom, 18 inches in height and taper to 4 inches square at the top. They are placed on a concrete base embedded in rock. The two reference monuments at Cape Muzon are 36 inches square at the bottom, 28 inches in height and taper to 8 inches square at the top. In special cases where the mountains are too rugged to place monuments, small brass bolts 18 inches long and one inch in diameter are used to mark the boundary. The bolts have a slit in one end and are wedged into the rock. The positions of the monuments, bolts, and the various mountain peaks constituting turning points of the boundary are determined geographically by triangulation.

A vista is cut through the timber and brush, throughout the land of the boundary. A skyline of about 20 feet is left making a line of about 40 feet wide on the ground in the valleys where large timber exists.

The glaciers along the Alaska-British Columbia boundary are the largest in the world, except those in the polar regions. The existing glaciers of Alaska are chiefly confined to the mountain regions, and these mountain snowfield and glacier belts average from 40 to 120 miles in width.

On our expeditions over the glaciers the variety of food was very limited. Tea, sugar, pilot bread, bacon, beans, Australian onions and evaporated apples constituted the rations allowed. The fuel used in cooking the food was kerosene and wood alcohol, using a special stove made for this purpose. This is quite a contrast to the menu served where transportation was easy. From the above list of rations, it can be seen that the more difficult the transportation happened to be, the smaller the variety of food. In our camps and inlets there was not much wanting in the food line.

Transportation was a big problem on the coast boundary, more commonly known as the "Panhandle." Canoes were used on all the rivers, and tracking them up the swift water was very tedious and dangerous. The back packing of supplies and survey outfit over the glaciers also proved to be very hard work as well as very dangerous. The crossing of the Malaspina Glacier from Yakutat Bay to Boundary Peak 4875, near Mt. St. Elias, was partly back packing for about 50 miles, sleds being used where the ice was not too rough.

The Commissioners have agreed that the southeastern Alaska sheets shall be prepared, engraved and printed under the direction of the British Commission on a scale of 1 : 250,000 in sheets covering 1° of latitude and 1° of longitude; also that a general chart on a scale of 1 : 1,000,000 to serve as an index shall be prepared in sheets covering 4° of latitude and longitude. Individual maps on such scales as shall be found advisable, of important river crossings, passes, etc., will also be prepared. The area mapped along the southeastern Alaska coast, including the mapping done in 1893, 1894, 1895, is about 36,000 square miles, mostly done by the Canadians, using the photo-topographic method. This was done under the direction of Dr. W. F. King, C.M.G., H.B.M. Commissioner.

A triangulation was made along the coast and expanded inland up the many rivers and inlets to make a network to determine the positions of the various kinds of boundary marks. Bases were measured on most of the river banks and inlets and

an azimuth observed. Our computations are all based on the southeast Alaska Datum, for longitude and latitude. To give an idea of the results obtained on this work, I will cite the triangulation along the Portland Canal. This scheme extends over a distance of 100 miles and checks on a C. and G. S. line to within 1/10 of a metre. The twist in azimuth is only 23 seconds. This check is good as the triangulation had to be narrowed down to figures three or so miles in width, to allow the tying in of the reference monuments at tide water. Berger's 6-inch theodolites were used, using the repetition method. The average elevation of the triangulation stations is 2500 feet and the average length of the lines about 5 miles. In the more rugged parts of the boundary, 4-inch Berger's theodolites were used and in many places for topographical purposes 3-inch Troughton and Simms mountain transits were used.

The two reference monuments at Cape Muzon are determined by a primary triangulation, expanded westward from the mainland in the vicinity of Prince Rupert, B.C., making use of Stephens, Dundas, Graham, Langara and the Prince of Wales group of islands. One line is 66 miles in length. A concrete pier, 18 inches square and about 40 inches in height, is erected at each station to set the theodolite on for the observer, which makes the setting of the instrument rigid. The pier contains 150 lbs. of cement, 400 lbs. of sand and the proper amount of broken rock to make a good concrete. The instrument is in two boxes, one weighing 160 lbs. the other 45 lbs. and it is quite a task to transport this instrument to the top of a 3000-foot mountain.

The primary stations are marked with a brass bolt either embedded in a concrete base or cemented into a drilled hole in solid rock. The observing pier of concrete is placed over the brass bolt, and in the top of the pier a 2-inch circular hole about two inches in depth is left directly above the brass bolt to allow plenty of play for the shank of the spindle of the theodolite. A wire nail is set in this hole to mark the centre.

The angle measures are made by the direction method with

a 12-inch theodolite. It is graduated to 5′ spaces and reads directly to single seconds by three micrometer microscopes. Each series of observations consists of successive pointings on the various stations, in order, from left to right with corresponding readings of the horizontal circle with three micrometer microscopes, followed immediately by pointings on the same stations in the reverse order after reversing the position of the telescope, by transiting it through the wyes and turning the alidade 180° in azimuth, each pivot remaining in contact with the same wye as before. Each observation of an angle consists therefore of two pointings on each station involved, one in each position of the telescope, together with the corresponding micrometer readings, 24 in all; both a forward and a backward reading of each micrometer being made in each of its positions. The angles are measured in 16 positions of the circle, commencing the 1st set of the first group at 0° 00′ 40″; 2nd set at about 15° 1′ 50″; 3rd set at about 30° 3′ 10″; 4th set at 45° 4′ 20″; first set of second group at 64° 00′ 40″; second set at 79° 01′ 50″, and so on. In each of the four groups of four positions each, the readings of the three microscopes on the circle corresponding to pointings on the initial station will be nearly uniformly spaced at intervals of approximately 15° over the whole 360°, and therefore the mean values of the angles from each group of four positions will be but little affected by periodic errors of graduation. In connection with this statement it is necessary to keep in mind that during each measure the alidade is turned 180° between the direct and reverse readings when the position of the telescope s changed, and therefore the three microscopes, which are at intervals of 120°, furnish readings at nearly uniform intervals of 60° during each measurement.

In each group of four positions the micrometer readings corresponding to the initial station, and, therefore, those corresponding to each station, are almost uniformly distributed over the 5′ interval covered by the micrometer. The effect of this is to insure that if a correction for run is applied, the algebraic sum of such corrections for each micrometer corresponding to

pointings on each station will be nearly zero. In other words, the mean value of any angle from observations in four positions, uncorrected for run, is almost independent of the run.

With each micrometer microscope pointings were made upon the circle graduations with two pairs of lines about four minutes of arc apart. With this arrangement of lines one reading, called the backward reading, is made on the graduation adjacent to the zero and to the apparent left, with the apparent left-hand pair of parallel lines. The other, the forward reading, is made on the graduation adjacent to the zero of the micrometer and to the apparent right, with the apparent right-hand parallel wires. The minutes of the readings are taken from the backward reading as usual. With this arrangement of lines but one turn of the micrometer head is necessary between corresponding backward and forward readings instead of five when a single pair of parallel lines is used.

The mean of the closing errors of a series of triangles on primary triangulation should be less than 1″ of arc. The closing error of any one triangle should not exceed 3″ of arc. All of our triangles on the primary work of the Alaska boundary close inside 1″ of arc but one, and this exception is inside of 2″ of arc. Lateral refraction was likely the trouble.

Zenith distances of the various stations, being a secondary consideration, are not measured until all horizontal work is completed. They are measured with a 6-inch Berger's theodolite.

Our experience in observing long lines over water is that the greater the elevation at each end of a line, the better the visibility. Fog is a great draw-back to intervisibility in the neighborhood of large bodies of water, such as Dixon Extrance, where it usually lies in a bank of from five to ten hundred feet in thickness.

Along the north end of Graham Island it is very rare not to have fog covering the shore to the height of about 500 feet during some part of the night, and as our Tow Hill station is only 500 feet in elevation and near the beach, it was very hard to see the light here from the various other stations. Most of

our pointings are made at night on rays of light from acetylene lamps. The pointings for the horizontal angles are made by using two parallel lines about twenty seconds of arc apart in the diaphraghm of the telescope. This lamp has a twenty-eight litre burner with a seven-inch mirror, reflecting lens, and shows a light of about 400 candle power. This burner consumes approximately one cubic foot of gas per hour generated from a tank that will hold about one-and-half-pounds of carbide, and a pint of water. This will keep the lamp burning brightly for about eight hours.

Pointings were not made to any extent on heliotropes, as some of the most experienced observers have decided that the best results can be obtained at night. As pointings on heliotropes are always made in the afternoon with the sun in the south-west, he unequal heating of the theodolite by the sun may cause your north and south lines to be pulled westward and your east and west lines southward. The heliotropes were used for signalling as well as the lamps, using the continental Morse alphabet. The signalman would watch for signals in the afternoon from the observers, light their lamps one hour before darkness and stay on duty until 11 o'clock. If no message had been received by this time, they would return to camp, first making sure that their lamps would burn for the balance of the night.

An observer calls a lightkeeper by turning a steady light upon him until answered.

A lightkeeper calls an observer by sending the initial letter of his surname.

The person called, looks for signals by aid of a telescope.

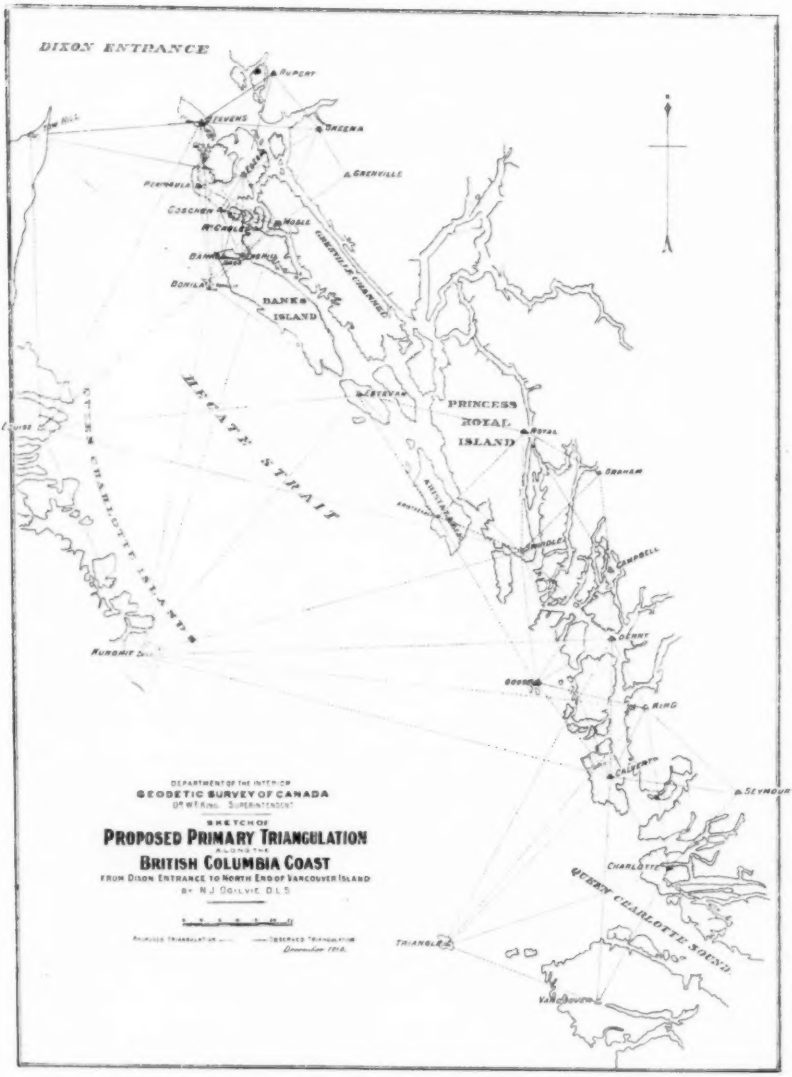
On some of the long lines two lamps were used, one placed vertically over the other, which seemed to make a brighter light. Two men were alloted to each signal station and four men for each observing party. In some cases four men for the observing party are not enough, especially in parts of British Columbia, while in easily accessible places three men are sufficient.

In former years the United States Coast and Geodetic Survey thought it necessary to go to excessive trouble and expense to

secure very long sides, 100 miles long being common, with many sides in excess of even this. The minimum length of such work on the United States Coast and Geodetic Survey is now 38 miles. The specifications for this work state that there is little, if any, advantage in so far as accuracy is concerned, in making the lines much longer than this. Instead of the excessively long lines and attendant large expense, it is better practice to use that length which will make the total cost of the work of reconnaissance and angle measurement a minimum per mile of progress. The short lines are used where frequent bases can be measured and wherever frequent La Place stations can be established without involving great expense. It seems to me that pointings on a short line are not as good as on a long line, and should your instrument not be properly centred over a station, the shorter the line the more the error.

Along the British Columbia Coast from Dixon Entrance to the north end of Vancouver Island, I would suggest using long lines if possible, such as this sketch of a proposed plan of triangulation shows. It takes in the Queen Charlotte group of islands and the various other islands along the mainland, as they are much more accessible than the rugged mountainous country of the mainland, where, if short lines are used, it is a question whether the work would cost less than using the long lines of this proposed scheme down the British Columbia Coast; besides, most likely your triangles would not have the necessary strength, owing to the many places that would be inaccessible, and other stations would have to be chosen that would probably make poorly shaped triangles.

The mainland of British Columbia, from the Skeena River to Rivers Inlet, is covered with exceptionally rugged mountains. The Grenville and Graham Channels are very narrow and the mountains in their immediate vicinity are of much greater height than the mountains on the west sides of Pitt and Princess Royal Islands, hence, one would have to use short lines in an attempt to come south, making use of just Pitt and Princess Royal Islands, as it is impossible to choose stations on their west sides



MAP TO ILLUSTRATE THE OPERATION OF THE GEODETIC SURVEY OF THE BRITISH COLUMBIA COAST

and have them visible from the stations on the mainland owing to the high mountains on the east sides of these islands along the narrow channels just mentioned. Then, should an attempt be made to use the mountains along the Grenville and Graham Channels, and the mountains on the mainland for a system of triangles, there would be a long trail cutting to the various stations situated on the mainland. There would have to be a large force of men to complete the necessary work for each station. The great difficulty, would be the time lost transporting the necessary instruments, supplies and camp outfits to the inland stations. The country is too rough to use pack horses and it would be slow work and too costly to have the packing done by men. By the time an observer could move from his completed station to his next station and be ready for work, there would be time for 5 or 6 days of clear weather, then, just as he would commence observing it would be likely to start in to rain for 20 or 30 days. The next difficulty of short lines along the mainland of British Columbia is, that there would have to be about six stations to the one on the long lines crossing Hecate Strait. From this, one can conclude that the stations, although they may have long lines joining them, may prove to be the less costly. Besides any surveyor who has been along the British Columbia Coast knows that very few bases could be measured owing to the ruggedness of the country. The great trouble would be to expand from a base, if procurable. Now with short lines along the mainland and infrequent bases, there would be great trouble in holding your distance and to keep the twist out. Observations for gravity should be made in many places along the British Columbia Coast, as well as for azimuth and longitude.

The success of the triangulation depends in a large measure upon the intelligent investigations made in reconnaissance. The investigations should include the selection of the strongest and most feasible figures for the triangulation, also the location of base lines.

A thorough description of stations should be made as well as a sketch.

The heights of stations depend on the relative heights of the ground at the stations and of the intervening topograpy. If the surface is level, then the heights of stations depend only on their distance apart. In any case the distance apart is so important a function of the necessary height that it is well to know what the heights would have to be for level, open country.

The curvature and refraction for 10 miles is 57·4 feet, for 60 miles 2065·8 feet. The approximate formulæ to deduce the distance when you know the elevation of a station, also to deduce refraction and curvature when you know the distance are, as follows:—

$$\text{Distance in miles} = \frac{\sqrt{\text{height in feet}}}{\cdot 7575}$$

$$\text{Refraction and Curvature in feet} = \cdot 574 \left\{ \begin{matrix} \text{distance} \\ \text{in miles} \end{matrix} \right\}^2$$

Since the height of the station increases as the square of the distance, it is evident that the minimum aggregate station height is obtained by making them of equal height. Or, if the natural ground is higher at one station than the other, then the higher station should be on the lower ground, that is, when the intervening country is level. If, however, the obstruction is due to an intervening elevation, the higher station should be the one nearer the obstruction.

On reconnaissance in the mountains I would suggest the use of the camera and plane table, and visit the less prominent parts on the start; then when you visit the prominent peaks you will know just what can be seen. If the prominent peaks have been visited first, and one tries to find a certain point in an area of round topped mountains, unless the reconnaissance man has an exceptionally good bump of direction and locality, he may find that his round topped mountain is lost, where, had he visited this section on the start, his guessing would be over with. Recon-

naissance is really the most important part of geodetic surveying and should be done well ahead of the observing parties. If not, you will have the latter held up waiting for the signals from the new stations.

On the primary triangulation of the Great Lakes, three lines respectively, 100, 93 and 92 miles in length, were observed across Lake Superior, which could not have been done except that the refraction was found sometimes to exceed twice its average amount. From this information I would suggest that the reconnaissance party make small allowances for excessive refraction on the proposed long lines across Hecate Strait and Queen Charlotte Sound, should Dr. King approve of the large scheme of triangles.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
February, 1915.

THE GEODETIC SURVEY IN BRITISH COLUMBIA

By G. H. McCallum

THE Geodetic Survey of Canada was started in the early summer of 1905 by Mr. C. A. Bigger, D.L.S., of the Dominion Observatory, Ottawa. The first station occupied was King Mountain, about twelve miles north of Ottawa, and since then the Survey has gradually extended over Ontario, Quebec, Nova Scotia, New Brunswick and British Columbia. While the principles governing the organization and extension of the Survey are similar in all sections of the country, particular attention will be given here to the progress of the Survey along the southerly coast of British Columbia northward from the forty-ninth parallel of latitude.

From a topographical point of view the country between the southern part of Vancouver Island and the mainland is ideal for a primary triangulation. This may be seen from the character and mathematical strength of the figures and the base expansion in that section. The Strait of Georgia runs in a northwesterly direction and is here from twenty to twenty-five miles wide, and the coasts run in parallel directions with ranges of mountains of any height desired just back of them. From Chatham Point on towards Queen Charlotte Sound the channels take a sharp turn to the west and narrow down to two or three miles wide with high mountain ranges on each side of them, making figures of any size difficult to obtain. Here too, the mountains are heavily timbered on the summits while those to the south are mostly bare rock.

Generally speaking, the weather conditions on the southerly part of the coast are good for observing. As a rule, November, December and January are the worst months of the year for rain and fog. The balance of the winter and spring is uncertain and

there may be two or three weeks' rain at a stretch, followed by a similar period of fine weather, making good conditions for observing.

The summer months are usually dry and the air is filled with haze and smoke from the towns and forest fires, so that a wet summer gives more clear weather than a dry one. Taken altogether it was found that the spring and early summer were the best times for observing, as, indeed, they are in every other place that I know of.

North of Seymour Narrows the rainfall increases rapidly. The average annual rainfall at Victoria is about 29 inches, at Vancouver 59 and at Rupert 123, just about double in each case.

Beginning about the middle of the summer, clouds form regularly on the mountain summits and are a continual annoyance to the observer because they are often just on the summit sufficiently to obscure the light, while elsewhere the weather is good. Even in a gale of wind these clouds stick and seem to form afresh as fast as they are blown away. They are probably due to the fact that the temperature on the summits is comparatively low, and the warm air from over the sea is condensed on coming in contact with them. They occur on the higher mountains first and gradually settle down to the lower ones.

The first work done on the coast was in the late winter and spring of 1910 when Mr. Stitt, who has since left the service, but whom many of you know, laid out the preliminary reconnaissance. And it speaks well for the quality and quantity of his work that out of the 28 stations located by him, 24 were used in the final occupation which was completed as far as he went, only last fall. The work was divided into three usual steps, reconnaissance, preparations of stations and their final occupation by the observer.

The first step in a primary triangulation is the reconnaissance and it is first in importance as well as first in the order of procedure. The subsequent operations can be directed and controlled from the office, but the efficiency and economy of the survey will depend very materially on the skill, good judgment

and experience of the person who conducts the reconnaissance. His work is to the survey, what the location is to the railway; if it is faulty no amount of subsequent work spent on it will make it what it might have been. And there is nothing so disastrous to the progress of the survey as to start an observing party on a reconnaissance in which there are closed lines. At the best it will mean re-occupation of stations when the lines are opened, and it may mean abandonment of the whole scheme if the lines cannot be opened.

The reconnaissance is started by occupying a suitable elevation or point already fixed by a previous triangulation, and noting the directions and distances of all likely-looking points visible from it. The directions are obtained by an observation on the sun for azimuth, or by taking angle readings from some point, the position of which is known and can be plotted, or by magnetic bearings. The latter are not reliable. The distances are obtained by estimation. With practice, distances can be estimated with an error of from one-fifth to one-tenth. Particular notes should be taken of favorable looking points in the direction in which it is desired that the triangulation should proceed. These directions and distances are then plotted on the best available maps of the district and the approximate positions of the new points marked. These are then located and occupied in a similar way and thus the work progresses.

The selection of a point for a future station depends first, on its visibility from all other necessary points; second, on the character and mathematical strength of the figure of which it forms a part; and third, on its accessibility. Generally speaking high points are better than low points on account of less refraction and the possible future extension of the survey. Avoid low lines, or lines passing over towns. Bare rocky summits are best for permanence of marking and ease of preparation and occupation. On wooded elevations the observations are usually taken from the top of a tree; the top being trimmed, cut square off with a saw and the instrument mounted on the stump.

Preparing a station, means getting it ready for occupation

by the observer. First, it is marked. There are two ways of marking, depending on whether the station is on rock or soil. On rock, the station is marked by a ¾-inch copper bolt set in a drill hole with a fox wedge and molten lead poured around it. This bolt is stamped with *G. S. C.* and the year of occupation, and an eight-inch equilateral triangle cut in the rock around it. Two or three reference arrows are also cut in the rock pointing towards the station with similar bolts at their points. The distances to these reference bolts and their angular direction from a primary station are noted. The station bolt should be placed at a greater elevation than the reference bolts and where possible the latter should be placed on lines to other primary stations.

In soil, a station is marked by an underground mark placed below frost line, or at least three feet deep, and by a surface mark projecting sufficiently above the surface to be easily found. The underground mark is the usual copper bolt set in a boulder or mass of concrete, or tile pipe or some foreign material. The surface mark is of similar construction, set directly over the underground mark but not in contact with it.

The next step in preparing a station, is building a tower or clearing lines. The only towers in the British Columbia work so far are two at the extremities of the base line, twenty-five feet in height, and one sixty feet high on our station at Campbell River. The latter is built of rough timber cut near the station. Where the summit of the mountain is sharp and the trees are not valuable the quickest way is to clear out lines through the timber. One of the best ways of doing this is to get angle readings on the other stations from some point near the summit or, if no point can be found from which to see out, from the top of the tree, also a compass bearing to one of the stations. First clear out the line on the compass bearing till the station in that direction is visible, then turn off the successive angles and clear out the other lines. Or by taking the directions from a map and starting with a compass bearing or an observed azimuth. On flat hill-tops in heavy timber it is easier

to build a tower than clear lines, and in some cases, as at Campbell River, a combination of line-cutting and tower-building is found to be most effective.

During last season the preparation of the stations and the observing were combined. It is not a good scheme, as the observer and his lightmen make a cumbersome party to handle, and it is so large and scattered that part of the men are idle when there is much cutting to be done. The method followed was to put my two best pair of lightmen on the forward stations with the compass bearing of the different lines radiating therefrom. The station was then marked and the first line cleared out, and they were left with instructions to spend all their spare time in clearing out the remainder of the lines. When the observer came they helped him pack his outfit up to the station and clear out what lines were left. Thus little time was lost except on two or three stations where there was heavy cutting.

The final stage in the survey is the occupation of the station by the observer. The instrument used is the twelve-inch direction theodolite and the direction method is employed in reading the angles. With, say, five directions to be observed, the observer sets his horizontal circle near zero, points his telescope on the first or initial light and notes the readings, both forward and backward on the three micrometers ; and similarly on each successive light, round to and including the initial. After taking the readings on the initial light the telescope is reversed and the instrument turned through 180° and swung in a reverse direction back to the initial, reading on each light as it is passed. This completes one position on the horizontal circle. The complete program includes sixteen such positions started from sixteen different settings on the horizontal circle. For each direction there is a direct and a reverse pointing, making thirty-two pointings ; and six readings for each pointing make 192 readings for each direction. These may be finished nicely in about one hour, or two minutes to a pointing. Thus a station with five lines radiating from it will take six hours, which includes the closing on the initial. Under ordinary circumstances it is not

advisable for an observer to try and work faster than this. But if for any reason he considers his time limited, it is allowable to take chances with the results and hurry the micrometer readings.

The errors of the instrument are corrected as far as possible by the method of observation ; thus the reading of three micrometers is to eliminate the eccentricity ; the sixteen settings on the horizontal circle are taken to eliminate the errors of graduations ; the forward and backward readings and the four different micrometer settings are to eliminate the error of run in the micrometer screw. The allowable error in closing a triangle is one second ; that is, the combined errors of observer and instrument are not to exceed one second. The errors caused by external conditions can not be eliminated but only avoided by not observing when these conditions occur to any marked degree.

Too much attention cannot be paid to the descriptions of stations. The work required to establish the position of a station is more or less lost if at any future date it cannot be recovered on account of an ambiguous or faulty description. The object of a description should be to render the recovery of the locality and of the exact station point as easy and certain as possible at any time and by anyone unfamiliar with the country, but familiar with the kind of work. All essential facts should be stated but nothing should be put into the description which does not aid in the recovery or identification of the station. It should give the name of the observer and date of occupation ; the general location,—province, county and township; the particular location,— the lot and the name of the owner, or if unsurveyed, the popular name of the hill or locality and the name of the person in the district who would know most about its position. The nature of the station, whether rock or soil and the marking should be given. In rock, a full description of the marking with the directions and distances of the reference bolts. With three reference bolts great care should be taken in the measurements of the distances and angles because they check each other and any discrepancy will throw doubt on the subse-

quent recovery of the station. In soil, the depth and character of the subsurface mark, the character of the surface mark, the direction and distance of the reference mark should be stated. The best means of approach, giving information about railway or steamboat lines, and of trails if in unsettled country should be recorded, and lastly a topographic sketch or photograph of the immediate locality of the station, showing the station, and reference marks should be secured. In subsequent occupations a record should be filed, giving the name of the observer and date of occupation, the condition in which the marking was found and any changes or renewals that were made.

In British Columbia the descriptions are comparatively easy as most of the elevations used are marked on the Admiralty charts of the coast with their names and elevations, and it has been the rule wherever possible to locate the station on the summit of the hill; a hill or mountain has only one summit and to say that the station is on the summit is the most definite and simple description that can be given of it.

The following is an extract from the instructions to a reconnaissance man in the United States Coast and Geodetic Survey report of last year:—"No line of the primary triangulation outside the base nets should be less than six kilometers long. There is little if any advantage, in so far as accuracy is concerned, in making the lines much longer than this. Endeavor, therefore, in laying out the triangulation scheme, to use the economic length of line; that is, endeavor to use in each region lines of such lengths as to make the total cost of reconnaissance, building and triangulation a minimum per mile of progress, subject to the limitations stated in these instructions." These limitations refer to the character of the figures and their mathematical strength.

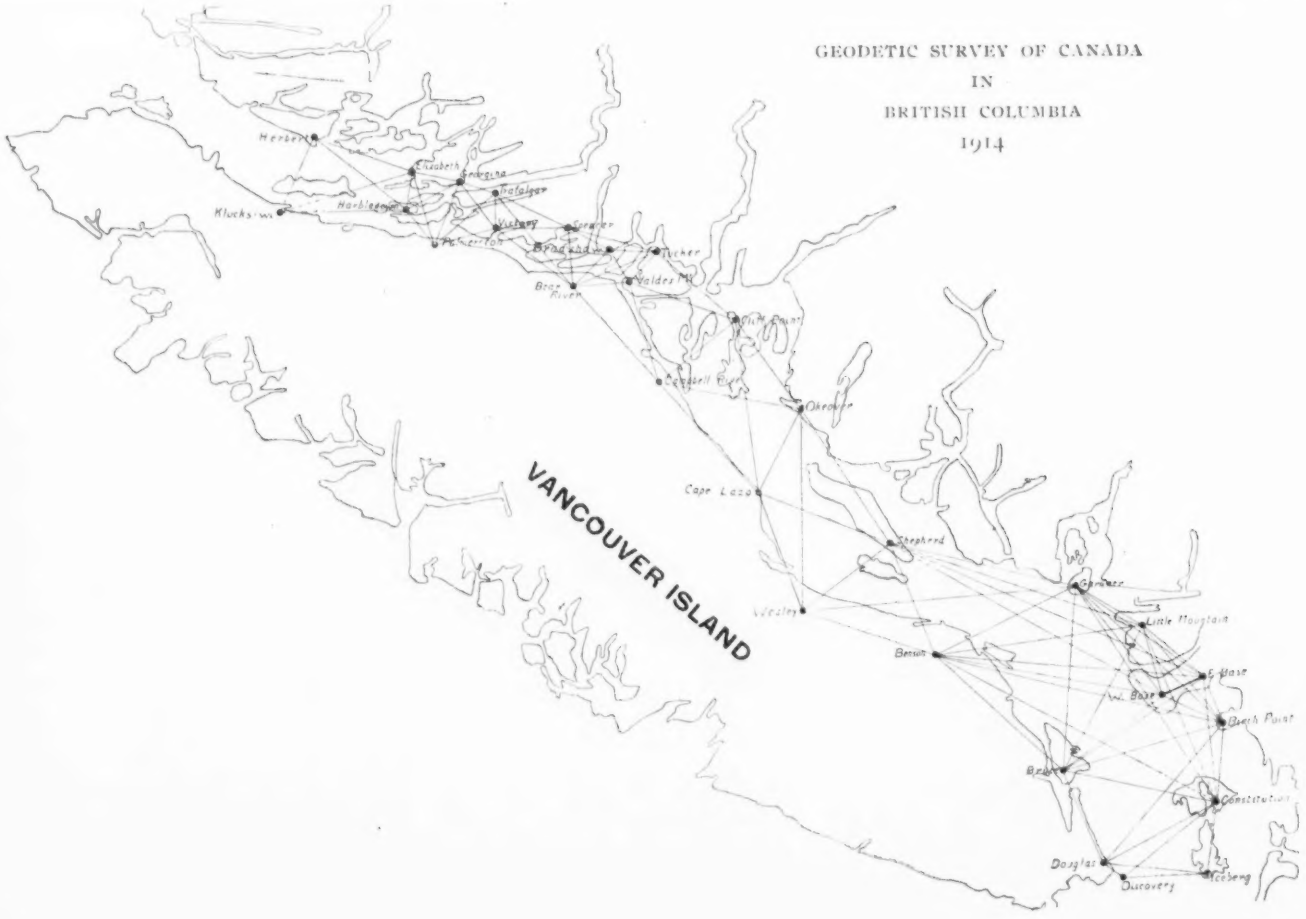
An illustration of this principle is seen by looking at the figures to the west of Tucker and Bear River (See Map). Here the main channel is Johnston Strait, two or three miles wide, with a continuous chain of mountains three to five thousand feet high running along the south side. To the north are irregular

GEODETIC SURVEY OF CANADA

IN

BRITISH COLUMBIA

1914



mountains two to four thousand feet high on islands and mainland. By keeping the stations comparatively low at about an average elevation of twenty-five hundred feet the figures were necessarily small, but the time taken up in occupying them was considerably reduced. The highest station, Bear River about 3700 feet, took twenty-eight days to occupy. This was in May and June, the best time of the year, and the delay was due nearly altogether to the clouds forming on the mountain at sunset and shutting out the lights. The same conditions prevailed on all the high mountains except for a short time in midsummer, and I am satisfied that better progress was made with the low stations and small figures than with higher stations and longer lines.

In recent years it has been found that while the computed lengths may keep within the allowable error, a twist occurs in the triangulation, making the geodetic azimuth differ from the true azimuth by an amount much greater than can be accounted for by the accidental errors in the observations. The cause of this deviation is not understood and in some cases it has been found to amount to as much as five seconds. It may be corrected by the introduction of a La Place point, that is, by observing for azimuth and longitude at a station in the triangulation. So that when a triangulation is weak from running through a difficult country or for any cause whatever, it may be brought up to the required strength by the introduction of such a point.

The base line in British Columbia is about seven-and-a-half miles long and is situated on the flat land at the mouth of the Fraser River about twelve miles south of Vancouver. The location is ideal for ease of measuring and for expansion into the main triangulation system. The base line was measured last fall by Mr. Moorehouse.

A year ago last summer the Department provided a new boat, the "*Metra*" to carry on the Survey, which is doing good work and is thoroughly appreciated. She is sixty-five feet long, fourteen feet beam and of fifty tons gross tonnage and has a speed of nine knots. At the stern is a large hold which will carry about a ton and a half of provisions and there is sleeping

accommodation for thirteen men without crowding. Her crew is a cook, engineer and a skipper. The character of the British Columbia coast is peculiarly suitable for navigation by small craft as they can run along it in inside channels for over a thousand miles. All the moving of the observing party and lightmen between the different stations was done with the *Metra* and she ran over 7000 miles last season. Back from the water the old familiar method of packing was necessary. Fuel and provisions were purchased in Vancouver and shipped up the coast by local steamboats and supplied to the different parties while being moved.

During last season, sixteen primary and three secondary stations were occupied. The average error in closing the triangles was ·92 seconds. The longest line from East Base to Shepherd is about sixty-five miles and the shortest from Victory to Trafalgar is about seven miles.

At the southerly end the triangulation has been connected with the American triangulation through the points Iceberg and Discovery. When the connection is made with Mr. Ogilvie's work to the north there will be a continuous triangulation from the Arctic Ocean along the one hundred and forty-first meridian, down the coast and into the United States Coast and Geodetic System which extends all over the United States.

DOMINION OBSERVATORY,
OTTAWA, CANADA.

OBSERVATIONS OF METEORS NEEDED

By S. A. Mitchell

WHO of us is not familiar with the darting rush of light through the sky which we call a shooting star, or in its more splendid forms, a meteor or fireball? Some of these objects are so faint that they are glimpsed only out of the corner of one's eye; some are so bright that they illuminate the landscape, and so close that the explosion is heard as they burst into fragments.

The popular impression regarding meteors is that they fall in a haphazard fashion, obeying no laws; and consequently, study of them would be futile. As a matter of fact, their systematic observation furnishes the amateur with a splendid opportunity to do work of great scientific value, and this may be done without an expensive equipment, and almost without previous training.

The amateurs in astronomy undoubtedly vastly outnumber the amateurs in any other science. There is a great fascination about observing the moon, or Saturn, or watching a double star, like β Cygni, with striking differences in color. The beginner feels greatly elated when he first obtains his three or four-inch telescope. He picks up, one after the other, the familiar objects in the sky, and takes particular delight in showing them to his friends. He generally finds, however, that the novelty soon wears off; there is no convenient place for setting up the telescope, clouds interfere, and as the winter comes on, the weather gets raw and the cold penetrates. And so, little by little the enthusiasm dies out — and soon there is a second-hand telescope for sale.

Fortunately for science, the human mind is constituted in

such a fashion that no task is too great to tackle, provided that the results to be obtained are of value. The tried astronomer can keep up his enthusiasm through a long night at the telescope even with the temperature twenty degrees below zero, because he has the feeling that he is adding something to the sum total of human knowledge. It is the lack of purpose in the work of the amateur that causes him to lose his interest and neglect his telescope. If the beginner could feel assured that his work was of value, he would cheerfully endure the cold, the discomfort and the lack of sleep. Many years ago in Chicago, an amateur started to observe double stars; and Burnham made of himself the greatest double star observer the world has ever known.

It was really not till fifty years ago, until after the wonderful shower of 1866, that the great importance of meteor observations was recognized. Schiaparelli showed that the August meteors and Tuttle's Comet moved about the sun in the same path; while it was soon demonstrated that the November meteors and Tempel's Comet, likewise, had a similar connection. When in 1872, Biela's Comet failed to re-appear, but instead there was a shower of meteors radiating from the point where the comet would have been seen, then it was evident that the connection between comets and meteors was not an accidental one. Biela's Comet was the first one to be seen to break up. A similar catastrophe has recently happened to Mellish's Comet as observed by Barnard, at Yerkes Observatory, on May 12, 1915.

The best theory regarding the tail of a comet is the light-pressure theory: that the particles forming the tail are repelled by the pressure due to the sun's light. As a result of this theory, the comet is slowly being disintegrated. The particles that once formed the comet's tail must, of necessity, follow nearly the same orbit about the sun that the head of the comet took. Consequently, each comet must have a meteor shower connected with it. These showers have been detected only in the case of some of the periodic comets. Olivier has shown conclusively that Halley's Comet has an attendant meteor shower, known as

the η Aquarids. He has observed some of these meteors in May 1915, five years after the return of Halley's Comet!

While the connection between meteors and comets is of the greatest importance, meteor observations are of great value to the meteorologist as well, since they tell him the height of he atmosphere, the drift of the upper atmosphere, etc,

Meteors in a shower move in parallel paths. These objects which are comparatively near to the observer are projected by the eye backward to the celestial sphere, with the result that, by perspective, the meteors all appear to radiate from a point — or rather small area — in the sky. Those meteors nearest the radiant have usually the shortest paths, those farthest away the longest. The meteor shower takes its name from the constellation in which the radiant is found. The accurate position of the radiant is specially desirable, and this may be found by anyone who exercises a little care and a little patience. The general plan for observing is to have a map before one specially prepared for the part of the sky where the observer is watching and put down on this map as accurately as possible the meteors as they are seen. If the meteor paths when produced backward are to intersect in the radiant, the positions of the individual meteors must be plotted with accuracy. This, however, with a little experience can easily be obtained.

Professor Charles P. Olivier, of the Leander McCormick Observatory, of the University of Virginia, has observed more meteors than anyone in America, and he is a recognized authority on their study. He has given the benefit of his experience in some printed rules, which if followed by a beginner, will make him a valued meteor observer. The National Academy of Sciences has awarded to the Leander McCormick Observatory a small grant for the purpose of encouraging meteor researches. Fortunately a series of valuable maps of the sky have just been published by Dr. Reynold K. Young, of the Dominion Observatory. These appeared in the January number of this JOURNAL, and were prepared specially for meteor observing. They fill a long-felt want. To all those who will engage in systematic

observations of meteors and who will write to the Leander McCormick Observatory, University, Virginia, a set of these maps and rules for observation will be sent free of charge.

The present time of year is a most auspicious one for the beginning of meteor observing. The weather is warm so that observations can be made in comfort. During the latter half of July and throughout August, a meteor may be seen by anyone who has patience enough to watch for ten or fifteen minutes, while two or three or even half-a-dozen may be seen in this time. The beginner should be cautioned against trying to observe when the sky is not perfectly clear, or when the moon is bright, for then only the very brightest meteors can possibly be seen.

Most astronomical work is valuable only when followed up regularly and systematically, but each night's work on meteors is separate and valuable by itself. Each observer will get full credit for all of the work which he sends in to the Leander McCormick Observatory, which by the grant of the National Academy has become the central bureau for meteor observations for Canada and the United States.

LEANDER MCCORMICK OBSERVATORY,
UNIVERSITY OF VIRGINIA,
June, 1915.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

May, 1915

Temperature.— The temperature was a little above the average from our Pacific Coast to the eastern limit of the Province of Manitoba, and below the average from Ontario to the Maritime Provinces, the deficiency being well marked everywhere. The chief positive departures were 2° at Barkerville, Medicine Hat, Battleford and Prince Albert, and the chief negative departures 4° at White River, Ottawa, Father Point, Chatham, N.B., and Charlottetown, and 3° at Southampton, Port Stanley, Kingston and Montreal.

Precipitation.— In British Columbia, the precipitation exceeded the average in Cariboo, but elsewhere was about average. In the Western Provinces, it was average or in excess of the average in the more southern portions of Alberta and Saskatchewan, but was somewhat deficient in the northern portions of these provinces and quite generally in Manitoba. Throughout Ontario and in the western part of Quebec, the precipitation was light and much below the average, whereas in Eastern Quebec and the Maritime it was heavy and much above the average. The most pronounced negative departures were Winnipeg, 1·20 inches; Parry Sound, 2·00 inches; Toronto, 1·20 inches; and Stonecliffe, 1·80 inches; and the chief positive departures were Medicine Hat, 0·90 inches; Swift Current and Qu'Appelle, 0·80 inches; Chatham, N.B., 3·60 inches, and Halifax, 3·10 inches.

Temperature for May, 1915

Station	May		Station	May	
	Highest	Lowest		Highest	Lowest
Yukon			Huntsville	79	24
Dawson	76	18	Kenora		
British Columbia			Kinmount	79	22
Atlin			Kingston	72	30
Agassiz	81	35	Lakefield		
Barkerville	72	28	London	78	28
Kamloops	84	38	Lucknow	74	25
New Westminster	65	47	Markdale	76	25
Prince Rupert	78	34	North Gower	78	28
Vancouver	72	35	Oshawa	70	30
Victoria	81	34	Ottawa	75	33
Western Provinces			Parry Sound	80	31
Battleford	80	30	Peterboro'	74	26
Calgary	78	31	Port Arthur	76	29
Edmonton	77	27	Port Burwell	78	27
Medicine Hat	82	28	Port Dover	70	32
Minnedosa	80	23	Port Stanley	75	33
Moose Jaw	80	18	Queensborough	69	30
Oakbank	79	29	Ronville	75	26
Portage la Prairie	80	25	Southampton	75	25
Prince Albert	78	27	Stonecliffe	76	28
Qu'Appelle	78	14	Stony Creek	79	26
Regina	80	16	Sundridge	79	31
Saskatoon	80	23	Toronto	70	20
Souris	80	25	Uxbridge	74	33
Swift Current	77	22	Wallaceburg	75	27
Winnipeg	81	24	Welland	76	31
Ontario			White River	73	31
Agincourt	76	30	*Quebec*	75	17
Aurora	77	25	Brome	76	29
Bancroft	71	24	Father Point	64	29
Barrie	77	30	Montreal	75	35
Beatrice	74	23	Quebec	77	32
Berlin	74	31	Sherbrooke	78	31
Bloomfield	71	31	*Maritime Provinces*		
Brantford			Charlottetown	66	32
Chapleau	74	24	Chatham	76	32
Chatham	79	30	Dalhousie		
Clinton	76	26	Fredericton		
Collingwood	79	30	Halifax	72	34
Cottam	77	31	Moncton		
Georgetown	76	32	St. John	69	32
Goderich	75	32	St. Stephen		
Gravenhurst	77	23	Sussex		
Grimsby			Sydney	70	26
Guelph	74	30	Yarmouth	68	34
Haliburton	82	21			

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. A.C. = Air Currents.
Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1915		P. T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
			h m	h m	h m	h m	mm.	h m	
1458	May	1	5 12·4 S 5 22·2	5 31·2	5 51·7	9 23·8	12·3	4 11·4	Sub-oceanic earthquake.
1459	"	1		9 25·9 } 9 29·5 }	9 31·1	9 58·2	0·2	0 32·3	
1460	"	1		11 19·7		11 33·0	0·1	0 13·3	
1461	"	2	4 31·2	4 44·4	4 50·7	5 20·9	0·4	0 49·7	
1462	"	3	3 45·9	3 55·1	4 5·7	4 47·5	1·3	1 1·6	
1463	"	3	4 50·2	5 3·1	5 27·7		0·4		
1464	"	3	6 6·4	6 21·6	6 22·9	6 40·5	0·3		
1465	"	5	12 4·8	12 20·2	12 30·8		0·3		
1466	"	5	13 13·2	13 28·7		14 6·0	0·2	0 52·8	Dual earthquake.
1467	"	6	12 17·5	12 29·4	12 31·8	13 1·3	0·8	0 43·8	[Beginning mixed up trailers of 1465.
1468	"	8		14 48·9 14 52·2	14 52·6	15 17·0	0 3		
1469	"	12	10 43·9	11 4·2	11 13·5	12 13·0	0·3	1 29·1	
1470	"	12	17 7·7	17 15·6	17 16·5	17 27·9	0·2	0 20·2	
1471	"	14	7 12·0	7 21·0	7 32·1	8 6·1	0·3	0 54·1	
1472	"	17	13 27·4		13 30·2	13 40·4	0·1	0 13·0	
1473	"	18		15 11 8		15 15·7	0·1	0 3·9	
1474	"	21		5 11·1	5 16·4 5 20·6	5 45·1	0·3 0·3	0 34·0	Repeat 5h 29m·5
1475	"	29		0 34·4		0 56·7	0·05	0 22·3	
1476	"	29		7 4·7		7 8·8	0·05	0 4·1	

Period 18 seconds. Pillar deviation 1 mm. = 0″·59.

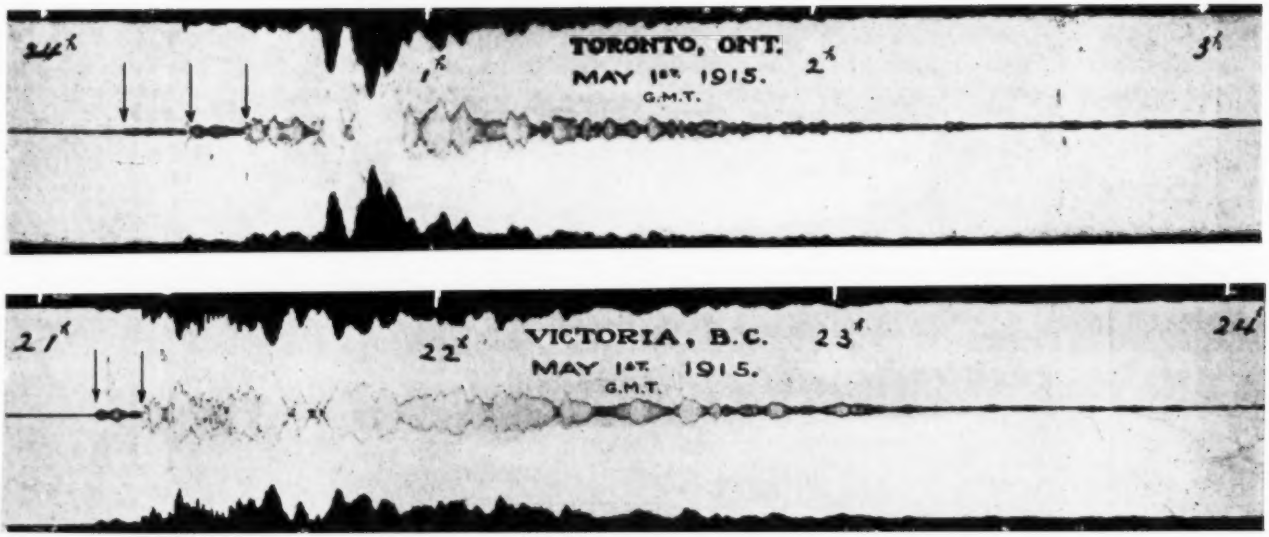
VICTORIA, B. C.

F. N. DENISON, SUPERINTENDENT.

No.	Date 1915	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1466	May 1	5 8 5	5 20·4	5 35 5	9 10·5	6·5	4 2·0	4·550 km. Phases well defined.
1467	" 1	9 12·5	9 20 0	9 20·5	9 53·5	0·3	0 41 0	
1468	" 2	4 32·4?	4 34·9	4 39·9	5 16·4	0·5	0 44 0	
1469	" 3	3 35·0	3 43·4) 3 47·4)	3 51·9	4 49·4	0·6		
1470	" 3	4 49·4?	4 52·4	4 55·4	5 37·4	0·5	0 48 0	Beginning mixed up (with trailers of 1466).
1471	" 3	6 1·8	6 7·7		6 39·1	0·05	0 37·3	
1472	" 5	11 56·3	11 59·3	12 3·8	12 32·3	0·2	0 36·0	
1473	" 6	12 12·9	12 13·4	12 14·9	15 8·4	4·0	0 55·5	
1474	" 8	15 2·5	15 10·5	15 12·5	15 27·5	0·1	0 25·0	
1475	" 12	11 14·1	11 24·1	11 33·6	12 2·1	0·5	0 48·0	
1476	" 12	16 56·1	17 0·6	17 1·6	17 5·6	0·1	0 0·5	
1477	" 14	7 7·7	7 13·2	7 17·2	8 2·2	0·3	0 54·5	
1478	" 17		13 44·0		13 46 0	0 05	0 2·0	
1479	" 21		5 30·9 5 35·7	5 38·1	5 44·7	0 05		Centre line very thick measurements doubtful.
1480	" 23	23 26·7	23 29·2	23 29·7	23 31·7	0·1	0 5 0	
1481	" 29	6 48·3	6 53·3	6 53·8	7 1·3	0·2	0 13·0	

Period 18 seconds. Pillar deviation 1 mm. = 0″·54

J. Y.



TORONTO, ONT.	h	m	s
Preliminary Waves	5	12	24
Secondary Waves	5	22	12
Long Waves	5	31	12
Maximum Amplitude	5	51	42
Final Waves	9	23	48
Amplitude 12·3 mm.			

VICTORIA, B.C.	h	m	s
Preliminary Waves	5	8	30
Secondary Waves	5	15	48
Long Waves	5	20	24
Maximum Amplitude	5	35	00
Final Waves	9	03	30
Amplitude 6·5 mm.			

RECORDS FROM MILNE SEISMOGRAPHS OF A SUB-OCEANIC EARTHQUAKE

The centre of the disturbance is indicated as being in the Pacific Ocean in the region north of the Sandwich Islands.

The maximum movement at Toronto indicates wave-lengths of 54 kilometres and about 37 centimetres in height; at Victoria 54 km. long, 14·5 cm. high.

MAGNETIC OBSERVATIONS, MAY, 1915

During the month of May, the disturbing forces acting on the magnetic elements, as indicated by the photographic records obtained at Agincourt, were fairly active. Only on three days are the curves classed as normal. The larger disturbances were on the 1st and 2nd, the 17th and 27th. In all cases the chief characteristic of the storms were their duration. A sunspot group was central on the sun's disc on the 2nd. The sun's surface was free from spots from the 8th to the 23rd, when another group of spots came over the eastern limb, being central on the disc about the 28th.

May, 1915		D. West	H	V	I
		° ′			° ′
	Mean of Month	6 27·8	0·16044	0·58658	74 42·6
	Maximum	6 42·9	0·16137	0·58719	
	Date of Maximum	1	1	1	
	Minimum	6 10·9	0·15951	0·58541	
	Date of Minimum	2	27	27	
	Monthly Range	0 32·0	0·00186	0·00178	
Mean Daily Amplitude	From hourly readings	0 12·8	0·00036	0·00019	
	From Means of Extremes	0 18·3	0·00070	0·00037	

H and V are expressed in C. G. S. Units.

I is the Mean of all Dip observations made during the month with the Earth Inductor, without regard to the time of day at which they were made. Two observations are usually made each week.

ASTRONOMICAL NOTES

THE AGE OF THE EARTH. — The discussions of the age of the earth by Lord Kelvin, in which he concluded that the temperature of the crust cannot have been near its present value for more than some 20-30 million years, have been seriously affected by the discovery of the radio-active elements. There is a general impression that Kelvin's arguments are entirely invalidated, and that it is permissible to assume a period of the order of some thousands of millions of years since the earth reached its present state as regards climate. This latitude has been hailed with much relief both by geologists and by astronomers who believe in the efficacy of tidal evolution, for the slowness of the processes of change demands great periods of time. In a letter to *Nature* (April 22), Dr. F. A. Lindemann argues that Kelvin's estimate has been thrown aside too hastily, and he makes out a strong case against any extension of the age of the earth and solar system.

Lord Kelvin's estimate was based on three independent considerations — the temperature gradient inside the earth, the amount of tidal friction, and the total amount of energy radiated by the sun. It is only the first of these that is affected by the discovery of radio-activity, and it is admitted that the corresponding argument is invalidated. In this connection it is pointed out that the temperature of the earth is such that it radiates an amount of energy just equal to the amount which falls on it from the sun — in other words, the earth's temperature is determined by that of the sun, and so long as the sun

preserves its present rate of radiation the earth will remain in its present state of temperature. The problem is thus brought back to the question of how long the sun can have radiated at its present rate. From this aspect, not much difference is made by taking radio-activity into account. Sir Ernest Rutherford has pointed out that even if the whole sun were made of uranium, this would only add five million years to its duration as a heat-giver. The possibility that at the high temperature of the sun the disintegration of atoms may be accelerated and extended to ordinary elements is considered; but, on general grounds, it is shown that this hypothesis may be dismissed. It is shown, too, that if the sun was formed by the collision of two extinct stars (stars in which the radio-active materials must have disintegrated long ago), the duration of its heat-supply would be unaffected by radio-activity. A certain part of the energy of collision would be used up in forming radio-active substances, and this would be liberated as they disintegrated; the total energy available to maintain the life of the sun would be unaffected by this temporary withdrawal and restoration.

Dr. Lindemann favors the collision theory for the formation of stars, because he sees in it an explanation of the great concentration of energy, under which alone the radio-active elements could spontaneously form. It appears to us, however, that if we are to accept his limitation of the life of a star (as a luminous body) to about 20 million years, the collision theory becomes impossible. To maintain a stellar system of a thousand million luminous stars would involve about 50 such collisions a year. Apart from the statistical improbability of this, it may fairly be urged that we ought to see something of these collisions.

It will probably come as a surprise to most readers to learn how insecure is the claim for long periods of time for evolutionary processes; and it is important to realize that the supposed sanction of physics is practically non-existent. We doubt, however, if astronomers will be willing to sacrifice, for example, Darwin's theory of the origin of the moon to this conclusion, and can only hope that some new revolution of thought will turn

the answer to this problem once more in our favor.— *The Observatory*, June, 1915.

In the issue of *Nature* of May 6th C. E. Stromeyer criticises Dr. Lindemann's conclusions and in the issue of June 3rd Dr. Lindemann thus replies:—

Mr. C. E. Stromeyer states that two conclusions in my letter published in your issue of April 22 are not correct; he claims, first, that the amount of energy lost by the earth is not compensated by the heat received from the sun; secondly, that meteoric bombardment of the sun has been left out of account as a source of energy.

As to the first point, the amount of energy lost in consequence of the temperature gradient in the earth's crust is of the order $1{\cdot}33 \times 10^{-6} \frac{\text{cal}}{\text{cm.}^2\text{sec.}}$. As this is 6000 times less than the total amount radiated, no useful purpose would be served by taking it into account.

As regards the second point, any heat due to meteoric bombardment up to date has been taken into account, as the sun's mass as it is known to-day was inserted in the calculation.

Perhaps the purport of my letter was not as clear as I could have wished. It was not so much my intention to weigh the evidence for or against an age of some twenty million years, as to emphasise the point that neither radio-activity nor any other known cause will account for a longer period. I have lately had the advantage of discussing the subject with Professor Strutt, and must admit that the conclusions he has drawn from the helium contained in rocks appear unanswerable.

It would seem, therefore, that the origin of the sun's heat cannot be referred to any known cause.

Relations Between Proper Motions and Radial Velocities.—The following is a "Summary of Results" of an investigation of "The Relations Between the Proper Motions and the Radial Velocities of the Stars of the Spectral Types *F*, *G*, *K* and *M*," by J. C. Kapteyn and W. S. Adams, at the Mount

Wilson Solar Observatory, Carnegie Institution of Washington, appearing in the *Proceedings of the U. S. National Academy of Sciences*, January, 1915:—

1. The radial velocities furnish a very thorough test of he theory of the star streams. The results found the *F*, *G*, *K* and *M* stars are in close agreement with those we should expect from the theory as derived from proper motions.

2. The radial velocities of the stars of the smallest proper motions show the effects of the two star-streams with the same certainty as those of the other stars. The existence of the two star-streams is, therefore, proved at the greatest distances for which we have adequate data.

3. The *K* stars behave in general like other stars, but there are a few exceptional cases. These do not appear to be due to the absence of the second stream.

4. For all the spectral classes the average radial velocities show a regular increase with the proper motion.

5. Such a change of radial velocity is a necessary consequence of a velocity distribution (for the peculiar motions) different from that given by Maxwell's law.

6. A first approximation to the velocity distribution has been derived for the *K* stars. It explains the change of velocity with proper motion in a satisfactory manner.

7. Some positive indications have been found of a change of radial velocity with absolute magnitude, the brighter stars moving more slowly than the fainter stars.

"COMET has disrupted. (Mellish 1915*a*). Observations and photographs of Mellish comet at the Lowell Observatory by Mr. Lampland and Mr. E. C. Slipher, prove that the smaller nuclei, four in all, accompanying the comet, are slowly receding from it at the rate of about four seconds of arc a day, which indicates that the comet has broken up. The innermost attendant shows a stellar nucleus with the usual envelopes and the outermost seems itself to be disintegrating. What forces or accidents of approach have occasioned the disruption is not yet ascertained."—Lowell Observatory, May 24th. J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amatuers. The Editor will try to Secure Answers to Queries.

A BEAUTIFUL INSCRIPTION

The moon sinks yonder in the west
While in the east the glorious sun
Behind the herald dawn appears.
Thus rise and set in constant change
Those shining orbs, and regulate
The very life of this our world.

The above beautiful lines are on the Triumphal Arch of the Rising Sun at the Panama-Pacific Exposition, where, no doubt, they will be read by some of the readers of the JOURNAL. They occur in Act IV. of "Sakuntala," a drama by Kalidasa, the Hindu poet and dramatist, the "Shakespeare of India," who lived about 525 A.D. I was interested enough to look up the translation of the drama by Monier-Williams, and I find his version of this passage to be as follows :—

Lo ! in one quarter of the sky, the moon,
Lord of the herbs and night-expanding flowers,
Sinks towards his bed behind the western hills ;
While in the east, preceded by the Dawn,
His blushing charioteer, the glorious sun
Begins his course, and far into the gloom
Casts the first radiance of his orient beams.
Hail co-eternal orbs, that rise to set,
And set to rise again ; symbols divine
Of man's reverses, life's vicissitudes.

In the same poem occurs the following :—

> Soon, a resistless hero, shall he cross
> The trackless ocean, borne above the waves
> In an aerial car ; and shall subdue
> The earth's seven sea-girt isles.

According to the mythical geography of the Hindus the earth consisted of seven islands surrounded by seven seas. This undoubtedly suggested to Kipling the title of his volume, "The Seven Seas."

METEOR OBSERVATIONS — WORK FOR AMATEURS

The editor is glad to find space in this issue for the article by Professor S. A. Mitchell on the observation of meteors. This is a field in which amateurs can do valuable work, and it is hoped there will be many volunteers in it. While we are glad to receive a real message from anyone, we are especially pleased to welcome Professor Mitchell. He was born in Ontario, and educated at Queen's University, Kingston ; and though for a number of years his work has been south of the great lakes, he is still a Canadian. A brother, at the present time, is at the front fighting the battle for freedom. Professor Mitchell is Director of the Leander McCormick Observatory, at University, Va., and has been again awarded the Ernest Kempton Adams Fellowship by Columbia University, the money for which is being devoted to researches on stellar parallax by means of photography. His assistant, Dr. Charles P. Olivier, is a recognized authority on meteor investigations.

LADY HUGGINS'S BEQUESTS

From *Nature* we learn that Lady Huggins, who died on March 24th (see this JOURNAL for April, p. 149) left an estate of about £12,000, which is to be distributed as follows :

A sum not exceeding £1,000 to the Bedford College for Women (University of London) ; £500, and, if her estate is sufficient, a further sum of £500 for the erection of a memorial

in St. Paul's Cathedral to the memory of her husband ; £1,000, and if her estate is sufficient, a further sum of £1,000 to the City of London School, Victoria Embankment, for the endowment of a scholarship for the study of astronomy, tenable at Cambridge, to be called the "Sir William Huggins Scholarship"; and a sum of not more than £300 for finishing, editing and illustrating the book on which she was engaged, being the life of her husband. The residue of the estate, if any, is left to the City of London School.

BRILLIANT AURORAL DISPLAYS IN ONTARIO

AURORA JUNE 12

An interesting display of aurora, visible in some parts of Ontario, occurred on Saturday evening, June 12th, 1915. It was unusual in having the formation of a complete narrow arch of light across the sky through the zenith, which faded about 10.20 p.m. a little south of the zenith, where it finally disappeared. At Barrie, Mr. A. F. Hunter measured along the horizon the angle of the arch at 10.15 p.m. as approximately 25° north of west,—nearly the same as the ecliptic, and, therefore, issuing from the sun's position at that time. At the same minute, low down in the north, there was a glow of light, without streamers, which lasted until midnight ; so it is probable that at northern places good displays occurred. Seven or eight hours later thunderstorms occurred in the same localities, thus showing the close affinity between the two phenomena.

AURORA JUNE 16-17

At about 12.15 on the night of June 16-17 the present writer was roused by a persistent ringing of the telephone bell, and was informed by a thoughtful friend that a fine aurora was to be seen. It was magnificent. The entire northern half of the sky, from west round to east and extending to the zenith, was illuminated by bright vertical streamers, though the motion was not rapid. In the east and also in the west, at an elevation of perhaps 12°, were one or two narrow horizontal streaks like black stratus clouds,

which were suspected to be a part of the aurora though sufficient evidence was not obtained to make sure of this.

AURORA JUNE 18

Our Second Vice-President, Mr. A. F. Miller, was good enough to send us the following description of an aurora observed by him at Toronto on June 18th:

A very bright aurora occurred on the night of Friday, June 18th, and during the early hours of the following day. I first noticed it as a strong glow of greenish hue forming a segment of a circle in the northern sky a little after 11 p.m. It did not then attain much altitude, the western upper limit of the illuminated arc being no higher than Capella, while in the east it was below the constellation of Cassiopeia. But it continued to increase in brightness and to gain in altitude as the night went on. Great patches of vivid green light occasionally bordered with fainter purple tints shifted rapidly from point to point along the arch, fading in places as they brightened in other positions. Towards midnight streamers began to shoot up, beginning at the eastern side and gradually spreading westward. About half an hour after midnight they had formed a crown reaching to the zenith. At this time the dark segment was of a dull purple color and just below it I could see some stars quite distinctly, though I cannot assert I saw stars *through* the dark segment. I was then obliged to discontinue my study of the display, but have no doubt it might have been watched till rendered invisible by morning twilight. I did not attempt spectroscopic observations as I was feeling greatly fatigued after the work of the day; the opportunity was, however, a good one for an investigation of that kind owing to the exceptional brightness of some of the streamers and patches. I would be glad to know whether any of our members made spectroscopic observations that night, using gas spectra for comparison.

I had no doubt the aurora was an accompaniment of solar activity and this conclusion proved correct. The following day I counted five groups of spots on the solar disc, comprising about

twelve spots easily visible in the small instrument I was using ; (a terrestrial telescope of 2-inch aperture having a power of 25 diameters). There was a very conspicuous group of spots forming a line that looked like a gash plowed straight along the white solar surface ; this group, evidently the seat of much activity, was almost on the sun's central meridian when I was observing. I may add it is still visible and now approaching the limb over which it will pass in course of a day or two Its general features have not greatly altered since June 19th but the individual spots of which it is composed have undergone marked changes due to vast activity in that region. It would be of interest to know the phenomena visible on the limb when the group is passing out of sight.

It may only be a coincidence, yet it is all the same a curious one, that great auroral displays occurred during the winter of 1870-71, while the Franco-Prussian war was in progress. One in particular was remarked during the seige of Paris and is recorded in Flammarion's valuable work "l'Atmosphere." I remember this aurora very well, it having been visible here. This fact remained in my memory because I had never before seen such a remarkable display ; I have, however, seen more wonderful auroræ since.

Have the unknown forces which operate on the solar surface causing sun-spots also a disturbing effect on humanity, arousing in mankind mental and physical excitement leading to deeds of violence ? Of old, auroræ were associated with wars and calamities, and justly, if we may believe ancient historians and chroniclers. Soon after the middle of the nineteenth century English men of science claimed to have proof that, sun-spot cycles had as their accompaniment calamities of diverse kinds. That active sun-spots are simultaneous with auroral displays is, I think, very generally admitted. I have just cited a case in point, and could cite many other similar instances coming under my own observation. Poets have long maintained the traditional association of auroræ and national misfortunes. A poet of the Victorian period wrote :—

"All last night the northern streamers shot across the trembling sky;
"Fearful lights which never beckon save when kings and heroes die."

For myself I must admit I have seen many fine and wonderful auroræ, even blood-red ones, unaccompanied by any such tragic events. Doubtless, in the olden time when deeds of violence were frequent, it was easy to establish coincidences which strongly supported superstitious beliefs of the kind we have been considering. As we are now, were there to be a great aurora each night the morning papers would supply enough horrors to justify us in concluding, that the opinions of our ancestors on the subject are being fully sustained in the light of modern experience.

A DAYLIGHT AURORA

[*Communication*]

On April 22nd I witnessed an auroral display, though the sun lacked a half hour of sunset. A "Daylight Aurora" is surely an oddity and the conditions permitting it to be seen would doubtless interest you.

I was at Viking, Alberta, 53° North Latitude. Night after night I had the pleasure of observing the activities of this electrical wizard of the north, and, naturally, I was alert to the possibilities of detecting any evidence of an aurora in the daytime. Success crowned my efforts on the day stated.

The air was delightfully clear and crisp. An occasional cloud appeared throughout the sky at high altitudes. It was 7 o'clock in the evening and for some time the sun was obscured by one of these clouds.

The display was seen in a portion of the sky with its centre about 25° or 30° east of north. Here there was a perfectly clear belt of the sky extending along the horizon for about 20° or 25° and upwards for about 10°. Above this clear space hung a dark cloud, as though it were a curtain arranged for the performance. This reached upwards some 20°, and against it the aurora was seen.

Numerous bright, hazy, milk like streamers, appearing to

have their source just below the cloud, darted upwards, rising about 15°. Each streamer had a quivering, shimmering motion, and at times a wave-like effect seemed to travel across the series of streamers, much as, in a wind, a wave passes over a field of standing grain. On reaching the right or left side of the dark curtain, the wavy appearance faded into the bright sky beyond.

A half dozen besides myself were the interested audience.

H. B. COLLIER.

CONTEMPLATION OF THE HEAVENS

These are troublous times. The mind is filled with thoughts on the awful tragedy being enacted in Europe, but it is well to pull ourselves away from such painful considerations and, surely, no more suitable subject for contemplation is afforded to us than the heavens. Perhaps the following extract from Flammarion's "Popular Astronomy" (Gore's translation, p. 628) may be suggestive to some readers.

Beautiful summer evenings which slowly descend from the heavens on the bright day, still come to bathe the earth with your golden halo! Open still to the perfumed breeze, the gates of the winding valleys: allow still to fall like dew of the air, the mist of the twilights; let the harmonious tints which imperceptibly fade away from the rosy west to the azure zenith still adorn this superb vault, that our delighted gaze may always wander in this floating depth! Sweet hours of evening, do not flee away. We love this universal calm which surrounds nature before it sleeps; we love this unchangeable peace which descends from the rising stars! Be present still at this profound meditation, in which all beings participate as if they had consciousness; listen still to the last rustling of the quivering foliage. The starry sky which lights up, the earth which falls asleep — these are spectacles which draw us away from a world of clamorous passions, pleasures of the soul which we enjoy in peace. But, whatever O beautiful evenings, may be the pleasure of your contemplation, however delightful may be the moments which you give us, the first stars which you light up in infinity will always be there to attract us more powerfully still, to enrapture more closely our attention and our thoughts. They tell us that if the earth is beautiful, and if man can draw precious gratification from his abode, the heavens are more magnificent still, and should be for us an inexhaustible source of study, of contemplations always new, and of intellectual pleasures incessantly reviving.

C. A. C.